Old Plant, New Tricks— MBR Retrofit: How to Maximize Performance While Minimizing Costs & Distruptions

– Marie-Laure Pellegrin and John Hatcher –

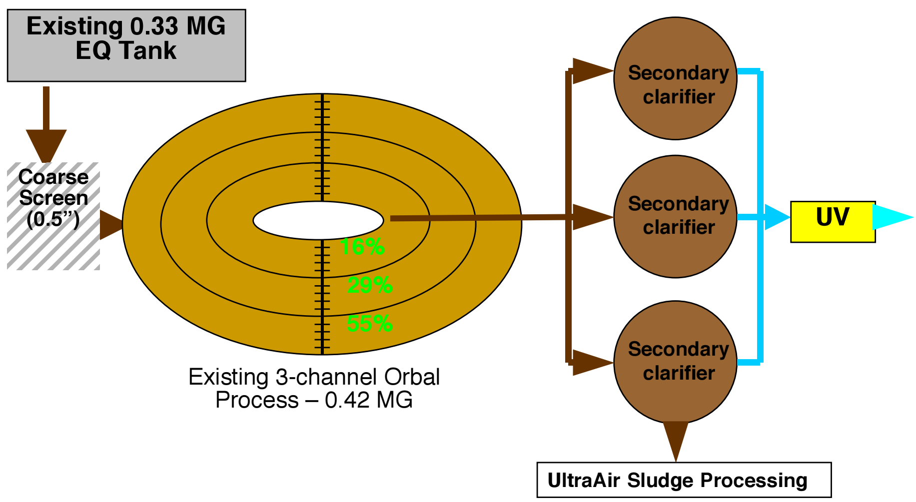

Figure 1: Calls Creek Flow diagram before Upgrade to the MBR Process

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The Calls Creek Wastewater Treatment Plant in Oconee County, Georgia, has had a longstanding policy restricting the wastewater plant usage for residential use in order to leave enough treatment capacity to accom-modate commercial business. An expansion increased its wastewater treatment capacity from 400,000 gallons per day (gpd) to over 670,000 gpd. In the future, the plant will be expanded to 1 million gallons per day (mgd) to accommodate commercial growth, as well as service to unincorporated areas for future use.

The project requirements for the Calls Creek expansion were:

- To increase the plant capacity with minimum changes to the existing infrastructure.
- To minimize the impact on the plant operation during the expansion.
- To incorporate the ability to phase the project by buying only what was needed at the current start-up conditions of the new system.
- To reuse the existing UV system with no changes.
- To improve effluent quality.
- To implement the most cost-effective alternative.

The Facility before Upgrade

The wastewater entered the plant via a 0.33 million-gallon (MG) equalization tank, then was directed to a 0.5-inch coarse screen before entering the 0.42 MG Orbal™ system, a three-channel looped reactor activated sludge process. The mixture of microorganisms and wastewater then flowed to three 20-foot diameter clarifiers with a 12-foot water depth. The effluent from the clarifiers gravitated to the ultraviolet (UV) disinfection system, a Parshall-Flume flow measurement, and a re-aeration step before being discharged to the creek.

The sludge at the bottom of the clarifiers was returned to the Orbal system. A portion of this returned sludge was diverted to the UltraAir sludge process for sludge wasting. The sludge was finally thickened on a belt filter press and disposed of. The flow diagram is shown in Figure 1.

Pilot Set-up & Results

At the start of this project, a pilot study was performed to demonstrate the technology, provide operator training, and familiarize operators with this new technology. The study lasted three months and was performed in two distinct phases.

The first phase used a conventional biological nutrient removal (BNR) setup where

Table 1: MBR Pilot influent and Effluent Water Quality for Phase 1 and Phase 2

Parameters	Influent	Effluent
Phase 1		
BOD, mg/L	111	1.3
TSS, mg/L	140	
NH_3-N, mg/L	12.4	0.1
PO_4-P, mg/L	7.0	3.8
Turbidity, NTU		0.06
Phase 2		
BOD, mg/L	152	0.9
TSS, mg/L	155	
NH_3-N, mg/L	15.1	0.1
PO_4-P, mg/L	6.5	0.8
Turbidity, NTU		0.06

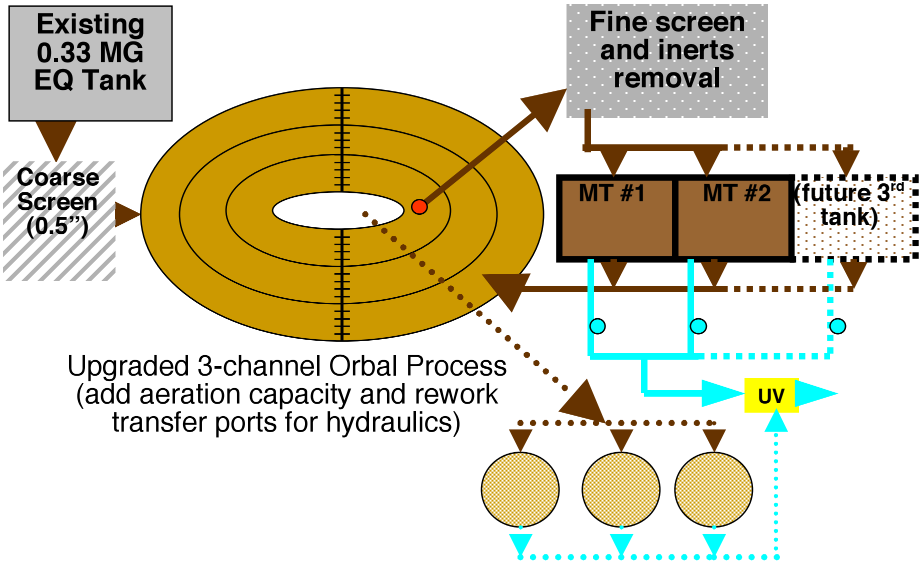

Figure 2: Calls Creek Flow Diagram after Upgrade to the MBR Process

the fine-screened wastewater flowed through an anoxic zone before entering an aeration basin and being pumped to the membrane tank. The sludge then overflowed from the membrane tank back to the anoxic zone. The filtrate was pumped out and discharge into the Orbal basin of the full-scale system.

The second phase of the study used the full-scale Orbal tank as the biological process upstream of the membrane tank. Sludge was pumped from the Orbal system to the membrane tank and overflowed back to Orbal system. The filtrate was pumped out and discharged into the Orbal basin of the full-scale system. This second phase was meant to give the Calls Creek staff confidence that the process will work with their existing setup.

The pilot provided very good, reliable effluent quality that is summarized in Table 1.

The type of process used upstream of the membrane tank did not affect the effluent water quality, as expected, which gave great confidence to the operators and the Calls Creek staff that using membrane bioreactors was a viable retrofit option for their facility.

Facility Upgrade to Membrane Bioreactor

The membrane bioreactor technology fit all six objectives of the facility upgrade at a competitive price (Objective Six): It was cheaper to simply add membrane tanks than to build another green field plant at another site (the current site did not have any room for adding another process and clarifier train).

First, minimum changes to the existing facility were made (Objective One). The flow continued entering the plant through the existing 0.33 MG equalization tank. Wastewater then flowed directly to the 0.42 MG Orbal system, by flowing through the existing 0.5-inch coarse screen. The only modifications on the Orbal system were to add aeration capacity and to rework the transfer ports for hydraulic purposes.

From the third loop of the Orbal system, sludge was pumped to two new ultrafine screens with a nominal opening of 250 microns. These screen 100 percent of the forward flow, plus the recycle flow between the Orbal system and the new membrane tanks.

Three membrane tanks were built, with only two currently in operation for Phase Two of the expansion. The third one was provided empty for Phase Three (Objective Three).

The overflow from the membrane tanks is directed to the first loop of the Orbal system. The effluent from the membrane tanks flows through the existing UV disinfection system, which did not require any upgrade given the higher transmissivity of the MBR effluent (Objective Four). The effluent goes through the same Parshall-Flume flow measurement and the same re-aeration step before being discharged to the creek.

The sludge is wasted by diverting some of the flow (that goes from the fine screens to the membrane tanks) to the UltraAir sludge process for sludge wasting. The sludge is finally thickened on the same belt filter press and disposed of.

One feature of this facility is that it keeps the three clarifiers tied into the Orbal system in case the flow exceeds the design peak flow of the membrane system. This security measure was desired by the client in case of unusually high flows caused from hurricanes.

Figure 3 shows the process layout of the upgrade to the membrane bioreactor process.

There was minimum impact on the plant operation during the expansion (Objective Two). The membrane building and associated equipment was built as a side-stream train of the conventional activated sludge system. The only ties-in were the submersible pumps in the third loop of the Orbal system to bring the mixed liquor through the fine screens, the overflow piping from the membrane tanks to the first loop of the Orbal system, and the connection to the existing UV system—the last one being the most difficult one of the three.

The main equipment provided for Phase Two is as follows:

- Three 1,600-gpm submersible MLSS pumps from the Orbal to the fine screens; one is installed as a spare.

- Two 2,200-gpm ultrafine screens (0.25-mm openings).

- Two membrane tanks with 10 racks per tank.

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- Three 1,600-gpm recirculation pumps (one installed spare) that pump the sludge from the fine screen to the membrane tanks and that are also used to divert the waste activated sludge to the UltraAir sludge process.
- Three 840-scfm blowers (one installed spare) to scour the membranes continuously.
- Three 634-gpm filtrate pumps with VFD (one installed spare) to withdraw the clean water through the membranes.

It took about 14 months from design to completion mainly because of last-minute changes or issues, some of them listed below:

- A generator was added to the design of the plant.
- There were some rack design issues that the membrane supplier encountered, which delayed the installation of the membranes.
- There was not enough time budgeted for piping and layout drawings to be completed in time.
- The effluent permit took extra time and effort to obtain because the state was not familiar at the time with this technology.
- Some design changes added to the length of the project. For example, the filtrate pumps had to be relocated in a sump for space considerations, some walkway around the MBR basins had to be added and there was additional time spent to determine how to install the pumps and piping in the existing Orbal process with minor operation impact.

Overall, the implementation of the plant upgrade did not adversely impact the existing treatment system operation or performance. The membrane bioreactor has now been in operation since April 2004.

Membrane Biofactor Operation since Start-up

For the first two months of operation, the average daily flow was about 0.36 mgd. The two membrane tanks were in service and filtering at a constant flow rate of 150 gpm per tank at an operating flux of 5 gfd, with 11 percent relaxation time at an average transmembrane pressure (TMP) of 1 psi. No maintenance cleanings or recovery cleanings were performed during this period.

Because the membrane system was operating at very conservative flux and the power requirements of having two membranes tanks running were much higher than the conventional system, operation was switched in June 2004 to operate only one membrane tank. Since that time, the average daily flow has been about 0.35 mgd.

The membrane tank filtration pump in service is currently operated at a constant flow of 330 gpm at an operating flux of 13 gfd, with about 25 percent relaxation time at an average TMP of 1.9 psi. Maintenance cleans are performed once every two weeks. The membrane tanks are rotated once a month and a recovery clean is performed after taking the tank out of service. The non-operating tank soaks in the cleaning solution. If high flows come to the plant, both membrane tanks are put in service.

The impact of the MBR process on daily operation in comparison to the prior conventional activated sludge system is as follows:

- There is a reduction in daily testing, since there is, for example, no sludge blanket determination, SVI measurement, or filamentous bacteria monitoring because settleability is not an issue anymore.
- The sludge-holding capacity has improved since the MBR operates at higher MLSS concentration, allowing less wasting overall and longer sludge age operation; consequently, the belt filter press operational time has decreased and less polymer is needed for its operation.
- The UV performance has improved, given the high effluent water quality, which requires fewer cleanings of the lamp. Cleaning frequency went from once per week to once per month.
- Solids washout is not a worry anymore during high flows, since all solids go through the membrane system, assuring a very high solids retention at all times.
- The dissolved oxygen (DO) concentration in the mixed-liquor flow return from the membrane tanks to the first loop of the Orbal system has impacted the denitrification process.
- An increase power cost has also been observed because of the additional equipment provided, in comparison to the operation of clarifiers: high scour energy, sludge pumps and filtrate pumps.

After almost three years in operation, some improvements have been identified to the overall process.

- The Orbal aeration system offers limited flexibility to optimize the BNR performance of the system. The use of multiple aerator shafts with VFD for each loop will help optimize the DO in each zone of the reactor.
- Remote monitoring and emergency auto dialer is required for the MBR process because of the “total shutdown” nature of the MBR system.
- Manual overrides for all pieces of equipment are preferred over automatic procedures. The system is sometimes perceived as too automated.

Conclusions

The Calls Creek Wastewater Treatment Plant upgrade, from conventional activated sludge system using oxidation ditch process to MBR, was overall very successful. It allowed increasing the plant capacity to more than two times its capacity in the same footprint with minimum changes to the existing infrastructure. The impact of the expansion on the plant operation was also minimal, since the membrane operating system was built as a sidestream of the clarifiers, allowing only three fairly easy ties-in.

Because of the high effluent water quality of a membrane system and the higher transmissivity of the effluent, the UV system was able to be reused as is, with fewer lamp cleanings than before the upgrade.

Finally, no changes to the solids handling processes were made. The membrane bioreactor, being operated at higher MLSS concentration and consequently higher sludge age, produces less sludge than the conventional system.

Overall, the system was well designed and does not require much operator time to operate. It has adapted well to the existing plant infrastructure with minimum changes and modifications. The effluent quality is excellent and very consistent, independent of the flow coming into the system.